

A HUMAN FACTORS TESTBED FOR GROUND-VEHICLE TELEROBOTICS RESEARCH

G. K. Corbett, S. M. Killough, and B. S. Richardson
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831-6005

M. Herman
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

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Abstract: A human factors testbed has been designed for the U.S. Army Human Engineering Laboratory to experiment in the area of remote control of wheeled vehicles. The testbed's capabilities have been demonstrated by remotely driving a high maneuverability and mobility wheeled vehicle (HMMWV). Details of testbed design and experiments are presented.

Introduction

The modernization of U.S. Army weapons and vehicles has increased the need for human factors research as applied to combat control stations. The U.S. Army Human Engineering Laboratory is concerned with fielding telerobotic combat vehicles and studying the human-machine-interface (HMI) requirements for control of these vehicles. Several obstacles must be overcome in order to remotely control battlefield vehicles. Optimum physical layouts and functional specifications of HMI components must be determined for specific tasks and environments. Also, methods need to be devised to improve operator performance while driving telerobotic combat vehicles under various degrees of sensory deprivation.

Sensory deprivation can take two forms; one is imposed upon the operator by the constraints of battlefield requirements while the other is due to the limitations of remote sensor technology. The latter form of sensory deprivation can be compensated for by improving the HMI through improved sensor placement and coordination of sensor positioning with advanced operator interfaces (e.g., cameras moving in coordination with teleoperator head position). While this study has not implemented such techniques, it has indicated several additional types of sensors and interfaces that would be helpful to the operator in particular situations. An

example of the former type of sensory deprivation is that which results from the use of secure (spread spectrum or frequency hopping) radios for communication in the battlefield. Standard video information requires a wide bandwidth and a direct line of sight between the transmitter and the receiver.¹ Video information for battlefield telerobotics must be compressed into a baud rate standard for data-radio channels so that low-detection radios can be employed for all remote-vehicle communication; however, temporal and spatial compression of video data greatly distorts the quality of the scene being viewed. Various video-compression techniques can be implemented for telerobotic operation, and the testbed described here has (and will be) used to determine the optimum compression technique for remotely driving wheeled vehicles. In addition, the sensory deprivation resulting from video compression can also be compensated for by improving the HMI as mentioned previously.

The testbed described in this paper was designed to carry out some initial human factors studies aimed toward solving the problems associated with teleoperation of wheeled combat vehicles. Two major areas of concentration for this research are (1) determining the optimum video compression technique and possible video enhancements (such as graphic overlay) for remotely driving wheeled vehicles, and (2) studying the HMI configuration and the combination of advanced sensors and graphics in order to ascertain the best HMI design for various combat scenarios.

Testbed Design

A human factors testbed has been designed specifically to remotely drive the HMMWV (See Fig. 1). The HMMWV, supplied by the U.S. Army Human Engineering Laboratory, has driving actuators and a low-level control system with an RS232 interface installed by Kaman Corp. In order to remotely control the HMMWV, video and data communication links were added to the existing control system. The HMMWV

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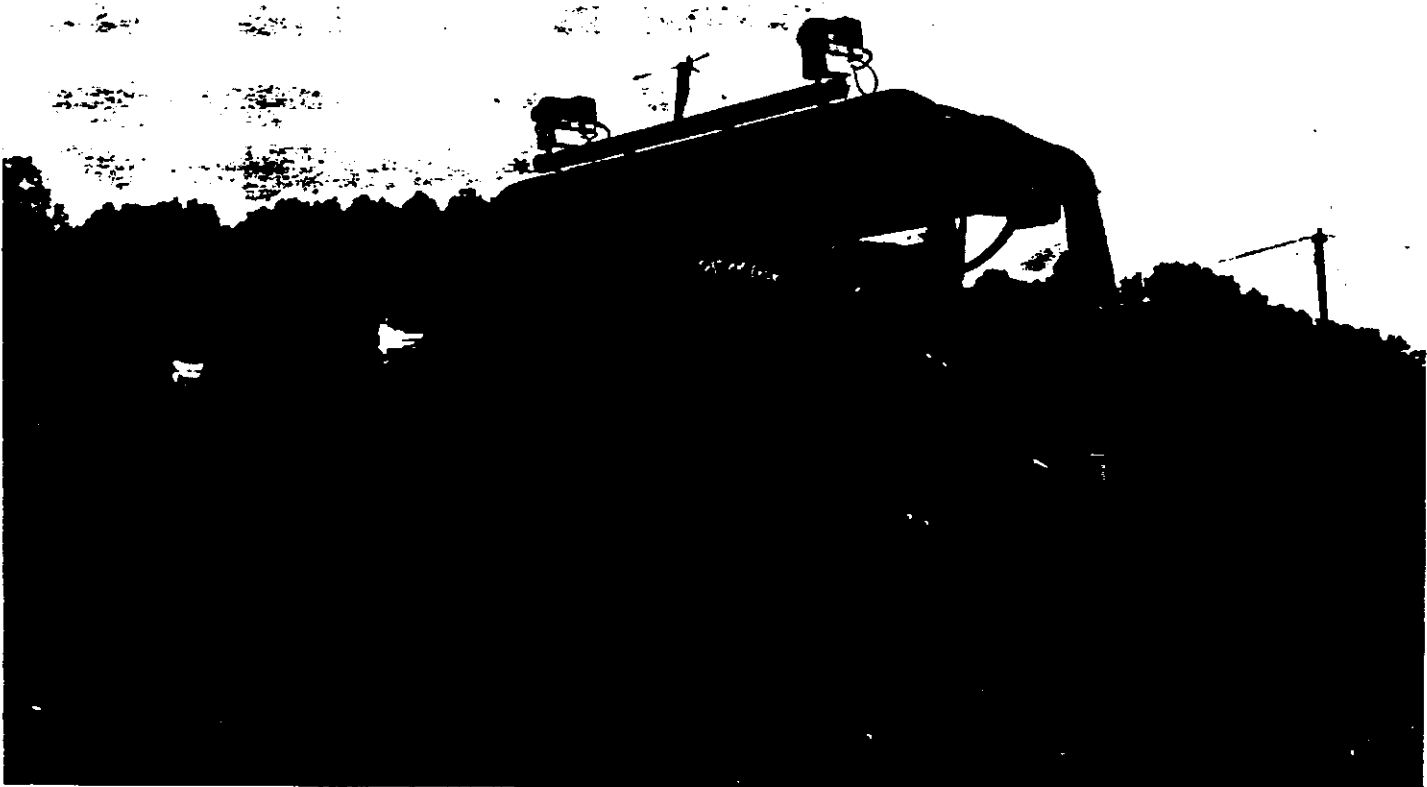


Fig. 1 HMMWV.

communicates with the HMI using a 19.2-Kbaud half-duplex data radio and two standard broadcast television channels (corresponding to each of the video cameras mounted over the windshield as shown in Fig. 1). The video and data-radio antennae are mounted on the rear corners and above the front windshield respectively; this configuration provides maximum separation between the video and data antennae, thus avoiding interference among the three signals. The data antenna had to be elevated above the plane of the video cameras in order to eliminate actuation of the cameras' auto-irises during remote vehicle communication. A VME-based computer is installed in the HMMWV to interface the data radio and the Kaman box (both RS232). The actuator commands are updated by the Kaman system at a frequency of 10 Hz.

The HMI for remote control of the HMMWV is shown in Fig. 2. The VME computers in both the vehicle and the HMI use a 32-bit bus with a Motorola 68020 CPU and the OS-9™ real-time operating system by Microware Systems Corp. The graphics interface for the HMI is provided by a Macintosh II, which communicates with the VME computer over an RS232 serial interface.² The HMMWV is remotely controlled through an interface similar to the one in the vehicle. Speed and direction are derived from brake and gas pedal and steering wheel positions: starting or stopping the engine and gear selection are provided through the graphics interface. Vehicle speed, engine RPM, fuel level, engine temperature, battery voltage, alternator temperature, and vehicle status messages also are displayed on the graphics interface. Video camera attributes are not presently remotely controlled; however, joystick and pull-down-menu inputs are programmed into the HMI to accommodate future capabilities for remote adjustments of camera pan, tilt, and zoom. The VME computer at the HMI processes the graphics and analog operator inputs and transmits vehicle commands through the data radio; after the commands are sent, the

computer receives the vehicle status packet and communicates this information to the graphics interface. The Macintosh and data-radio interface drivers are run as parallel tasks to minimize serial-communication delays. Because the Macintosh and VME computer programs are written in C, program and data base constructs can be preserved across differing operating systems.

Color video information is displayed on two 13-in. monitors, one for each camera. One of the two monitors can be switched to view a compressed (black and white) version of the real-time video signal. A schematic diagram of the testbed interfaces is shown in Fig. 3. Use of compressed video data to remotely drive a vehicle is termed low-data-rate driving (LDRD). True LDRD comprises digitizing and compressing the video information at the remote vehicle and decoding and displaying the images at the HMI. This testbed simulates LDRD in that the video is digitized, compressed, and displayed within the HMI. Given that the communication delays are programmed into the simulation, there is no discernable difference between teleoperation of a vehicle with simulated and with actual LDRD.

Testbed Experimentation

The HMMWV was remotely driven on a 1/8-mile gravel track 8 hours a day for 7 days. Obstacles and potholes were placed on the track to test the maneuverability of the vehicle. PIPE, a real-time pipelined image-processing machine, was used for the initial LDRD experiments with this testbed.³ Image compression and reconstruction are achieved on PIPE using decimation and Poisson interpolation.⁴ The video refresh rate during LDRD is ~7 frames/s.

Various problems were encountered while performing this initial experimentation. The inherent delay between initiating a command at the HMI and actuation of the command at the vehicle could cause the vehicle to become unstable, particularly in situations that require quick response. For example, a sharp turn of the steering wheel at the HMI to avoid an obstacle close to the HMMWV would turn the vehicle away from the obstacle, but then it would be headed too far in the opposite direction; another sharp turn to compensate would then set up an oscillation with respect to vehicle position. One way to alleviate this situation would be to stop forward motion and start again with the wheels positioned as desired. This problem could be remedied under normal driving conditions with a faster communication link and a higher actuator update frequency; LDRD would require a slower speed of travel.

Difficulty was also introduced by the unrealistic quality of the scene being viewed. The placement and field of view for the cameras used in this experimentation tended to give the impression at the HMI that the vehicle was traveling much faster than its actual speed. In addition, depth perception was poor, making it difficult to discern between potholes and ground discoloration. This problem was intensified when operating in the LDRD mode because the scene was viewed without color, at fewer frames per second, and with some distortion due to the compression algorithm. A number of methods can be used to improve the quality of the video at the HMI. More cameras with greater fields of view can be used in conjunction with larger monitors; camera position adjustment can be coordinated with operator eye or head position to give the sensation of looking where one is driving; a helmet-mounted display also can be utilized, but it must be coordinated with specific tasks because it restricts the operator's view to just the video (and associated overlay graphics) when wearing the viewing device. In addition, there are a number of possibilities for improving LDRD. The video can be displayed in color; other compression techniques (such as the discrete cosine transform) can be employed; simulation of the imagery between frames at the HMI can improve the realistic quality of the video as well as allow images to be transmitted at a slower rate; graphic overlay can be used to display information such as the front of the vehicle, the horizon, or parallel lines extending forward from the sides of the vehicle.

Additional recommendations for improving the HMI include adding an audio sensor to give engine-state information, embedding force-feedback in the steering mechanism, and employing additional sensors for detecting obstacles outside the normal viewing range.

Summary

A human factors testbed has been designed to experiment with the teleoperation of wheeled combat vehicles. This testbed has been demonstrated by remotely driving the HMMWV using standard and compressed video techniques. This initial experimentation has provided insight into some key problems associated with remote driving, and a number of applications to improve the HMI for teleoperation of the HMMWV have been suggested.



Fig. 2 Human-machine-interface.

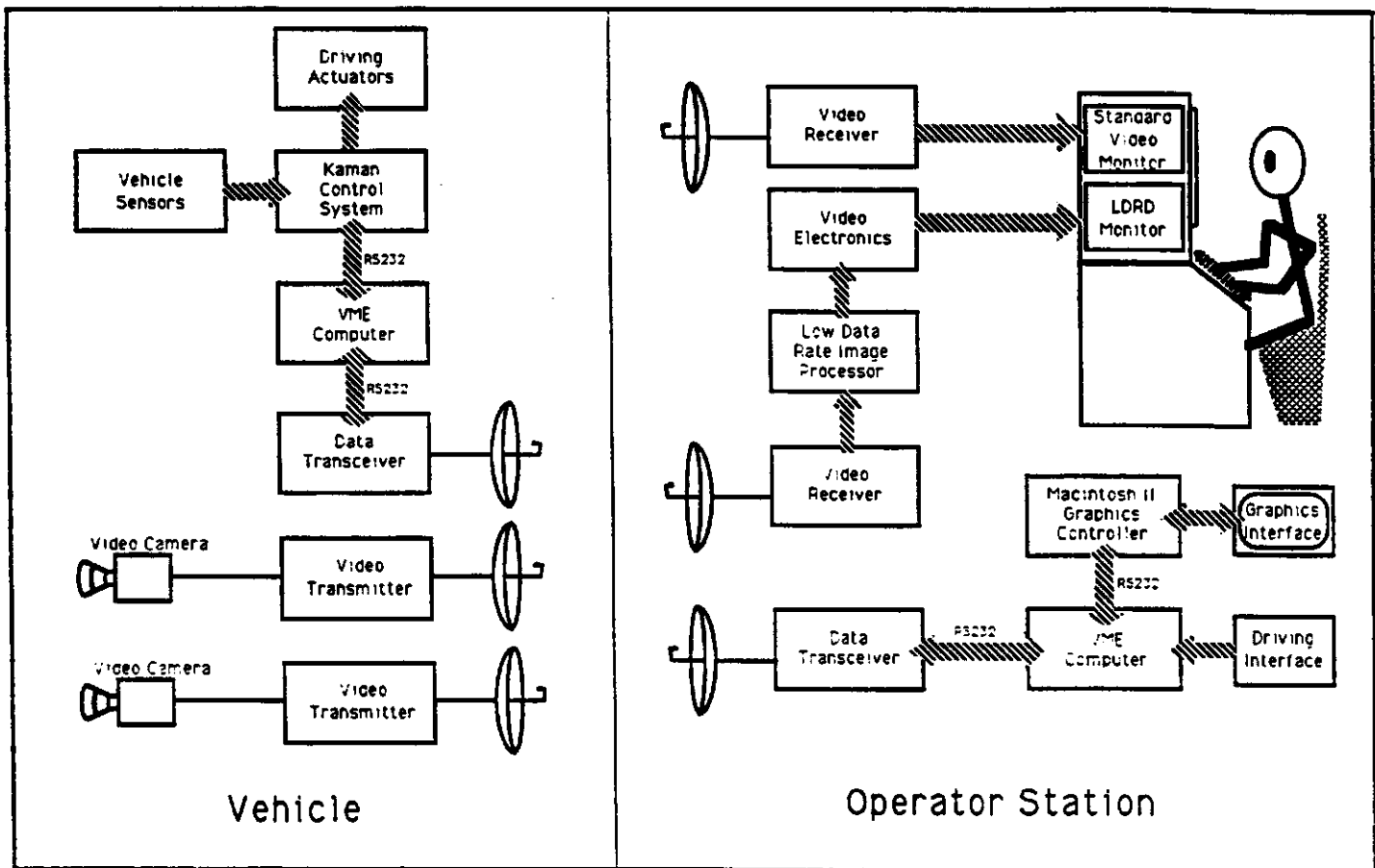


Fig. 3 Human factors testbed block diagram.

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